CLAIMS

1. An undivided electrochemical cell comprising:

a housing defining an undivided chamber, the housing having one electrolyte inlet and at least two outlets;

an anode in the chamber;

a cathode in the chamber; and

an electrolyte in the chamber,

wherein the anode and the cathode are not gas diffusion electrodes.

2. The undivided electrochemical cell of claim 1 wherein the housing has two electrolyte outlets.

3. The undivided electrochemical cell of claim 1 further comprising a fluid flow controller in fluid communication with the electrolyte outlets.

4. The undivided electrochemical cell of claim 3 wherein the fluid flow controller is selected from flow restrictions, valves, screens, fluid flow constrictions, bends or weirs.

5. The undivided electrochemical cell of claim 1 wherein the anode is made of a material containing iron.

6. The undivided electrochemical cell of claim 1 wherein the anode is selected from solid iron plate, expanded metal mesh, wire mesh, woven metal cloth, wire, rod, or combinations thereof.

7. The undivided electrochemical cell of claim wherein the anode is selected from iron, steel, "dimensionally stabilized anode"(DSA), titanium, platinum, iridium, and other oxidation resistant electrolytically conductive materials.

8. The undivided electrochemical cell of claim 1 wherein a ratio of a surface area of the anode to a surface area of the cathode is in the range of 1 to at least about 10.

9. The undivided electrochemical cell of claim 1, wherein said cathode has a physically displaced area that interfaces least 90%, and preferably about 100%, and most preferably 110% of the anode area.

10. The undivided electrochemical cell of claim 1 wherein the cathode is made of a material selected from nickel, titanium, platinum, tin, lead, stainless steel, graphite, iron or alloys thereof, or laminates or claddings thereof.

11. The undivided electrochemical cell of claim 1 wherein the cathode is selected from solid plate, expanded metal mesh, wire mesh, woven metal cloth, wire, rod, or combinations thereof.

12. The undivided electrochemical cell of claim 1 wherein the electrolyte is an alkaline solution of hydroxide.

13. The undivided electrochemical cell of claim 12 wherein the hydroxides are selected from NaOH, KOH, or combinations thereof.

14 The undivided electrochemical cell of claim 12 wherein the hydroxides are selected from >BioH, KOH, and combinations thereof.

15. The undivided electrochemical cell of claim 12 wherein the electrolyte comprises a mixture of KOH and NaOH, and wherein a molar concentration of NaOH is greater than about 5.

16. The undivided electrochemical cell of claim 15 wherein the electrolyte comprises about 40 to about 45 wt% NaOH and about 0.1 to about 8 wt% KOH.

17. The undivided electrochemical cell of claim 1 further comprising a screen between the anode and the cathode.

18. The undivided electrochemical cell of claim 17 wherein the screen is made of plastic.

19. The undivided electrochemical cell of claim 17 wherein the screen has a mesh size such to occupy at least 25%, preferably at least 50%, and most preferably at least 75% of the area between the anode and cathode surfaces, in which the open area consists of small openings, as is provided by a screen or the equivalent.

20. The undivided electrochemical cell of claim 18 wherein the plastic is selected from polyolefins, fluoropolymers, or polyvinyl chloride.

21. The undivided electrochemical cell of claim 1 wherein the housing is made of a material selected from metal, fiberglass, reinforced plastic (thermoplastic or thermoset) concrete, rubber, or combinations thereof, including constructed as a corrosion resistant liner within rigid-walled structure.

22. The undivided electrochemical cell of claim 1 further comprising a variable DC power supply operatively connected to the electrochemical cell.

23. A method of operating an undivided electrochemical cell comprising: Providing a housing defining an undivided chamber, the housing having an electrolyte inlet, at least two electrolyte outlets, an anode in the chamber, and a cathode in the chamber; introducing an electrolyte into the chamber through the electrolyte inlet; and controlling an amount of electrolyte flowing out of the electrolyte outlets so that substantially more electrolyte flows past the anode than the cathode.

24. The method of claim 23 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing a valve in fluid communication with the electrolyte outlets.

25. The method of claim 23 wherein the electrolyte inlet is located nearer to the anode(s) than the cathode and preferably located beneath the anode.

26. The method of claim 23 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing weirs in fluid communication with the electrolyte outlets, the weirs having different heights.

27. The method of claim 23 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing a flow restriction in fluid communication with the electrolyte outlets.

28. The method of claim 23 wherein a ratio of the amount of electrolyte flowing past the anode ($mL/cm^2/sec$) to the amount of electrolyte flowing past the cathode ($mL/cm^2/sec$) is at least approximately 60:40.

29. The method of claim 23 wherein a ratio of the amount of electrolyte flowing past the anode to the amount of electrolyte flowing past the cathode is at least about 70:30.

30. The method of claim 23 wherein a ratio of the amount of electrolyte flowing past the anode to the amount of electrolyte flowing past the cathode is at least 80:20.

31. The method of claim 23 wherein a ratio of the amount of electrolyte flowing past the anode to the amount of electrolyte flowing past the cathode is at least 90:10.

32. The method of claim 23 wherein a ratio of the amount of electrolyte flowing past the anode to the amount of electrolyte flowing past the cathode is at least 95:5.

33. The method of claim 20 wherein a ratio of the amount of electrolyte flowing past the anode to the amount of electrolyte flowing past the cathode is at least 99:1.

34. The method of claim 23 wherein the housing has one electrolyte inlet and two electrolyte outlets.

35. The method of claim 23 wherein a ratio of a surface area of the anode to a surface area of the cathode is at least about 0.8-1.2, including 1.0, preferably about 3 to 6, and most preferably 8-15.

36. The method of claim 23 wherein the electrolyte comprises an aqueous blend NaOH, and wherein the NaOH concentration can vary from approximately 17 % (5M) to 52% (20M), preferably from about 25-45%, more preferably from approximately 30-40 % (10.0-17.0M).

37. The method of claim 23 wherein the electrolyte comprises an aqueous blend of KOH and NaOH wherein the KOH concentration can range from about 0-15 % (0-3.0M), preferable from approximately 0.1 -10% (0.018-2.0M), more preferably approximately 0.5-8.0 % (0.1-1.5 M), and most preferably about 4-8% (0.74-1.5M).

38. The method of claim 23 wherein the electrolyte comprises an aqueour blend of KOH and NaOH wherein the KOH to NaOH molar ratio ranges from about 0.001 to 0.4, preferably from about 0.01 to 025, more preferable from about 0.1 to 0.25, and most preferably from about 0.08 to 0.12.

39. The method of claim 23 wherein the electrolyte comprises about 40 to about 45 wt% NaOH and about 3 to about 6 wt% KOH.

40. The method of claim 23 further comprising providing a screen between the anode and the cathode.

41. The method according to claim 23, wherein the ferrateVI is continuously harvested.

42. The method of claim 23 further comprising applying a variable direct current between the anode and the cathode, the variable direct current varying between a maximum voltage and a minimum voltage, the minimum voltage being greater than 0.

43. A method for making ferrate(VI) comprising:

providing an undivided electrochemical cell comprising an iron-containing anode, a cathode, and an electrolyte solution, wherein the electrolyte comprises an aqueous solution comprising a mixture of KOH and NaOH wherein a molar concentration of NaOH is greater than about 5 and a molar ratio of KOH:NaOH is less than 0.1; and applying a voltage between the anode and the cathode to form the ferrate(VI).

44. Method wherein the electrolyte compromises an aqueous solution NaOH concentration can vary from approximately 17% (5M) to 52% (20M) preferably from approximately 25-45% (8.4-17.0M), more preferably from about 30-45%(10.0-17.0M).

45. The method of claim 43 wherein the electrochemical cell has an electrolyte inlet and at least two electrolyte outlets.

46. The method of claim 43 further comprising controlling an amount of electrolyte solution flowing out of the electrolyte outlets so that substantially more electrolyte solution flows past the anode than the cathode.

47. The method of claim 46 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by valves in fluid communication with the electrolyte outlets.

48. The method of claim 46 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by weirs in fluid communication with the electrolyte outlets, the weirs having different heights.

49. The method of claim 46 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by flow restrictions in fluid communication with the electrolyte outlets.

50. The method of claim 43 wherein a ratio of a surface area of the anode to a surface area of the cathode is at least about 10.

51. The method of claim 43 wherein the electrolyte solution comprises about 40 to about 45 wt% NaOH and about 3 to about 6 wt% KOH.

52. The method of claim 43 further comprising providing a screen between the anode and the cathode.

53. The method of claim 43 wherein the voltage is a variable direct current voltage, the variable direct current voltage varying between a maximum voltage and a minimum voltage, the minimum voltage being greater than 0.

54. The method of claim 53 wherein the voltage has a frequency of between about 0.01 and about 1000 Hz.

55. The method of claim 53 wherein the voltage produces a current density of between about 4 and about 70 mA.

56. The method of claim 43 further comprising continuously filtering the ferrate(VI) from the electrolyte solution.

57. The method of claim 53 further comprising recycling the filtered electrolyte solution to the electrochemical cell.

58. A method for making ferrate(VI) comprising:

providing an electrochemical cell comprising an iron-containing anode, a cathode, and an electrolyte solution, the electrolyte solution comprising at least one hydroxide; and

applying a variable direct current voltage between the anode and the cathode to form the ferrate(VI), the variable direct current voltage varying between a maximum voltage and a minimum voltage, the minimum voltage being greater than 0.

59. The method of claim 58 wherein the minimum voltage is a voltage that substantially overcomes passivation at the anode.

60. The method of claim 58 wherein the maximum voltage is a voltage that exceeds a voltage needed to produce ferrate(VI).

61. The method of claim 58 wherein the voltage has a frequency of between about 0.01 and about 1000 Hz.

62. The method of claim 58 wherein the voltage produces a current density of between about 4 and about 70 mA.

63. The method of claim 58 wherein the electrochemical cell further comprises at least two electrolyte outlets, and further comprising controlling an amount of electrolyte flowing out of the electrolyte outlets so that substantially more electrolyte flows past the anode than the cathode.

64. The method of claim 63 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing valves in fluid communication with the electrolyte outlets.

65. The method of claim 63 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing weirs in fluid communication with the electrolyte outlets, the weirs having different heights.

66. The method of claim 63 wherein controlling the amount of electrolyte flowing out of the electrolyte outlets comprises providing flow restrictions in fluid communication with the electrolyte outlets.

67. The method of claim 58 wherein a ratio of a surface area of the anode to a surface area of the cathode is at least about 10.

68. The method of claim 58 wherein the electrolyte solution comprises a mixture of KOH and NaOH, and wherein a molar concentration of NaOH is greater than about 5 and a molar ratio of KOH:NaOH is less than about 0.1.

69. The method of claim 58 wherein the electrolyte solution comprises about 40 to about 45 wt% NaOH and about 3 to about 6 wt% KOH.

70. The method of claim 58 further comprising providing a screen between the anode and the cathode.

71. The method of claim 58 further comprising continuously filtering the ferrate(VI) from the electrolyte solution.

72. The method of claim 71 further comprising recycling the filtered electrolyte solution to the electrochemical cell.

73. A method for making ferrate(VI) comprising providing a housing defining an undivided chamber, the housing having an electrolyte inlet, at least two electrolyte outlets, an iron-containing anode in the chamber, and a cathode in the chamber;

introducing an electrolyte solution into the chamber through the electrolyte inlet, the electrolyte solution comprising a mixture of KOH and NaOH, wherein a molar concentration of NaOH is greater than about 5 and a molar ratio of KOH:NaOH is less than about 0.1;

controlling an amount of electrolyte flowing out of the electrolyte outlets so that substantially more electrolyte flows past the anode than the cathode; and

applying a variable direct current voltage between the anode and the cathode to form the ferrate(VI), the variable direct current voltage varying between a maximum voltage and a minimum voltage, the minimum voltage being greater than 0.

74. The method of claim 73 wherein the electrochemical cell has two electrolyte outlets.

75. The method of claim 73 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by valves in fluid communication with the electrolyte outlets.

76. The method of claim 73 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by weirs in fluid communication with the electrolyte outlets, the weirs having different heights.

77. The method of claim 73 wherein the amount of electrolyte solution flowing out of the electrolyte outlets is controlled by flow restrictions in fluid communication with the electrolyte outlets.

78. The method of claim 73 wherein a ratio of a surface area of the anode to a surface area of the cathode is at least about 10.

79. The method of claim 73 wherein the electrolyte solution comprises about 40 to about 45 wt% NaOH and about 3 to about 6 wt% KOH.

80. The method of claim 73 further comprising providing a screen between the anode and the cathode.

81. The method of claim 73 wherein the minimum voltage is a voltage that substantially overcomes passivation at the anode.

82. The method of claim 73 wherein the maximum voltage is a voltage which exceeds a voltage needed to produce ferrate(VI).

83. The method of claim 73 wherein the voltage has a frequency of between about 0.01 and about 1000 Hz.

84. The method of claim 73 wherein the voltage produces a current density of between about 4 and about 70 mA.

85. The method of claim 73 further comprising continuously filtering the ferrate(VI) from the electrolyte solution.

86. The method of claim 77 further comprising recycling the filtered electrolyte solution to the electrochemical cell.

87. A method for making ferrate(VI) comprising:

A. providing a housing defining an undivided chamber, the housing having an electrolyte inlet, at least one electrolyte outlets, an iron-containing anode in the chamber, and a cathode in the chamber;

B. introducing an electrolyte solution into the chamber through the electrolyte inlet, the electrolyte solution comprising at least NaOH, wherein a molar concentration of NaOH is greater than about 5.

C. Flowing electrolyte out the of outlet

D. applying a variable DC voltage between the anode and the cathode of sufficient amplitude to form the ferrate(VI), the variable direct current voltage varying

between a maximum voltage and a minimum voltage, the minimum applied voltage, being 0 or greater.

88. The method of claim 87, wherein the variable DC voltage is applied to obtain a voltage level where ferrate active film removal exceeds or equals net active film formation rate for a selected time period, said time period selected to substantially prevent excessive film growth.

89. The method of claim 87 wherein the minimum voltage is greater than 0.